NERRS Science Collaborative Progress Report for the Period 03/01/13 through 08/31/13

Project Title: Carbon Management in Coastal Wetlands: Quantifying Carbon Storage and Greenhouse Gas Emissions by Tidal Wetlands to Support Development of a Greenhouse Gas Protocol and Economic Assessment

Working Title: Bringing Wetlands to Market: Nitrogen and Coastal Blue Carbon (BWM: NCBC)

Principal Investigator(s): Alison Leschen, Manager, Waquoit Bay National Estuarine Research Reserve

Project start date: November 15, 2011

Report compiled by: Kate Harvey, Collaboration Assistant, Waquoit Bay National Estuarine Research Reserve.

Contributing team members and their role in the project:

- Omar Abdul-Aziz (Modeler), Florida International University (FIU)
- Steve Emmett-Mattox, (Intended User Representative), Restore America's Estuaries (RAE)
- Kate Harvey (Collaboration Assistant), Waquoit Bay National Estuarine Research Reserve (WBNERR)
- Kevin Kroeger (Applied Science Investigator), United States Geological Survey (USGS)
- Alison Leschen (Principal Investigator, Manager), Waquoit Bay National Estuarine Research Reserve (WBNERR)
- Jordan Mora (Research Assistant), Waquoit Bay National Estuarine Research Reserve (WBNERR)
- Kate Morkeski (Research Assistant and Applied Science Investigator), Marine Biological Laboratory (MBL)
- Serena Moseman-Valtierra (Applied Science Investigator), University of Rhode Island (URI)
- James Rassman (Stewardship Coordinator), Waquoit Bay National Estuarine Research Reserve (WBNERR)
- Tonna-Marie Surgeon Rogers (Collaboration Lead, CTP Coordinator), Waquoit Bay National Estuarine Research Reserve (WBNERR)
- Jim Tang (Applied Science Investigator), Marine Biological Laboratory (MBL)
- Thomas Walker, (Economist, Intended User Representative) Manomet Center for Conservation Sciences (Manomet)

A. PROGRESS OVERVIEW

This project is designed to address the interaction of two of the most critical management issues currently facing coastal communities, climate change and eutrophication caused by excess nitrogen loading. The project will generate information and tools that coastal decision makers can use to manage nitrogen pollution, design effective wetlands protection and restoration projects, and create policy frameworks and economic incentives to reduce greenhouse gas (GHG).

The fourth reporting period of project implementation (03/01/13-08/31/13) included: planning for and implementation of a second field season of data collection (summer 2013); analysis of data gathered by team members during the first field season (summer 2012); further honing of the model for predicting carbon storage in wetlands; continued work on a draft blue carbon methodology; and drafting of options for economic and policy analyses. The period also included engagement with intended users on coastal blue carbon and possible applications as well as initial discussions and scoping for deeper engagement around the model and economic analyses tools. Further detail on project goals and reporting period tasks are below:

Project Goals	Reporting Period Tasks and Accomplishments
A. Quantify carbon sinks and GHG fluxes in tidal wetlands, and assess the impact of anthropogenic nitrogen loading, sea level rise, and climate on both carbon sequestration and net GHG emissions in tidal wetlands.	• Continued monthly field measurement of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and net ecosystem carbon balance (NECB); • Continued measurement of lateral fluxes of carbon (C) and nitrogen (N); • Continued sediment, water, and plant measurements; • Continued analysis of data gathered in first field season (spring-fall 2012). • Adding photosynthetically active radiation (PAR) to the parameters measured (per the request of an intended user). • Adding soil moisture to the parameters measured (per the request of an intended user). • Adding non-destructive aboveground plant biomass to the parameters measured.
B. Develop a carbon sequestration and GHG emissions model for tidal wetlands using the collaboration between end-users and scientists to identify the specific data needs for it, and apply the model to aid the development of a tidal wetlands GHG offset protocol.	• Continued refinement of beta-version of model using preliminary data from initial field season for the BWM project.
C. Connect the conservation	• Continued work on a draft of the GHG

community with guidance on management of carbon and nitrogen and with carbon markets by providing a GHG offset protocol (methodology) that will be adopted by climate registries.	methodology. • Educated intended users about coastal blue carbon and potential applications through presentations and outreach materials.
D. Provide to intended users (resource managers, project developers, policymakers, land use planners, and those involved with carbon markets) data and a GHG offset model that can inform planning for tidal wetlands preservation and restoration.	• Delivered presentations and events to continue building interest in the BWM project among intended users, including local coastal-decision makers, NERRs staff across the country, salt marsh scientists, and non-governmental partners working in salt marsh restoration and management; • Designed and presented science translation products on key concepts related to the BWM project with input from intended-users.
E. Conduct an economic assessment of the carbon sequestration and GHG benefits of tidal wetlands, including the impact of nitrogen loading, to assess the financial relevance to land conservation decisions.	• Initiated scoping of economic and policy analyses options based on BWM team feedback, early stakeholder input (gathered in 2012), and data availability.
F. Advance the ability of the NERRS, building on its System-Wide Monitoring Program, Biomonitoring and Sentinel Site efforts, to monitor the effects of climate change on coastal ecosystems.	• Delivered presentations and events to continue to build understanding of key concepts and potential applications of the BWM project to NERRs across the country. • Completed work on one transfer- ideas-to-other-NERRS projects: a) Blue Carbon Demonstration and Dialogue and continued work on another b) BWM module development for Teachers on the Estuary (TOTE) Program.

B. WORKING WITH INTENDED USERS

During this reporting period, the team continued to engage in outreach to intended users, including the NERRS, local coastal decision-makers, agency and non-governmental coastal resource managers, salt marsh restoration professionals and scientists, and the public. The BWM team meeting in March 2013 included opportunity for field scientists and intended-users from RAE, FIU, and Manomet to discuss additional field data that would support their work. As a result of these conversations, the field investigators added several new data collection parameters to their 2013 field measurements (e.g. PAR and soil moisture). Additionally, the team's engagement continues to focus on building understanding of the key concepts related to the BWM project (e.g. coastal blue carbon and its potential relevance to intended users, potential influences of nitrogen on coastal blue carbon, innovative tools and methods used for field science, and the anticipated coastal management tools that will be available from this project). These efforts included:

Greenhouse Gas Methodology
RAE continued to conduct frequent outreach regarding the methodology. A sample of specific outreach includes:

- Briefed White House Office of Management and Budget staff, U.S. Fish and Wildlife Service International Program, Walton Foundation, and National Fish and Wildlife Foundation in February.
- Invited presenter at the World Ocean Council's Sustainable Ocean Summit in Washington, DC in May.
- Briefed NOAA's Office of Habitat Conservation on RAE's blue carbon initiative, including the methodology, in May.
- Worked with *National Wetlands Newsletter* Editor to develop a special issue on blue carbon lessons learned and identified and recruited authors. Discussion to be focus of Nov-Dec 2013 issue.
- Briefed the U.S. Congressional Sustainable Energy and Environment Coalition in May.
- Participated in the International Blue Carbon Science Working Group meeting in May.
- Worked with South Slough NERRS to submit funding proposal and received funding from NERRS Science Collaborative to hold blue carbon workshop.
- Briefed local partners, including land managers, tribes, and agency staff, in Puget Sound, through LightHawk flights, in May.

Engaging the NERRS and Partners in Coastal Blue Carbon
To facilitate engagement with the NERRS around the relatively new topic of Coastal Blue Carbon, WBNERR and RAE applied for and received funding from the NERRS Science Collaborative to host an on-site participatory assessment and dialogue about blue carbon and its potential applications. The event intended to: 1) build understanding of blue carbon and its potential applications among NERRS and partners 2) build capacity of NERRS and partners to implement carbon offset projects. Fifteen participants attended, including two Reserves (Waquoit Bay and Great Bay) and multiple conservation and land management organizations with whom regional NERRs often partner. The day-long event included presentation and discussion about blue carbon concepts, blue carbon markets, and potential applications for land managers. The event also included discussion and brainstorming about the potential applications of blue carbon at participant sites.

To engage a wider audience on coastal blue carbon, the project team also worked with Meg Gardner, University of New Hampshire TIDES program graduate student, to develop a brief educational video that includes an overview of blue carbon and provides information for Reserves, agencies, or landowners who may be considering how to incorporate blue carbon in their coastal wetlands projects and management strategies. The team also developed a six-page template about how NERRS, state and federal agencies, local organizations, or landowners might begin the process of implementing blue carbon strategies to help them achieve existing management goals for the estuary and/or region. This template includes information on the relevancy of blue carbon to a potential user; a series of next steps or considerations a potential user should pursue; and a list of resources/references on coastal blue carbon. The template was distributed to RAE's network of restoration practitioners and promoted to RAE's Constant Contact list of more than 9,000 interested individuals. The team is working with the NERRS Science Collaborative to determine the best way to roll out the video and template to the NERRS, including in conjunction with the NERRS annual meeting.

Engaging Teachers in the BWM Project

With support from a NERRS Science Collaborative Transfer Grant, Joan Muller, Education Coordinator at WBNERR and Tom Gaskill, Education Coordinator at the South Slough NERR in Oregon, developed an education unit for middle and high school teachers and students about the BWM project. The module includes concepts, findings, and interesting attributes related to the science, technology, and economic aspects of the project. Team members provided input to the TOTE project team on a draft curriculum, including outreach materials (DVD with movies of CT-scanned marsh cores) and content suggestions. Team members also participated in the demonstration of field techniques on August 14, 2013 in Sage Lot pond for K12 Teachers in the Blue Carbon module. For more on the TOTE project, see page 21.

Local Intended-User Engagement

In addition to the Coastal Blue Carbon materials described above, the project team continued to develop science translation materials for intended users and the public. The Collaboration Assistant continued to update the project website (www.wbnerrwetlandscarbon.net) which includes project updates, educational materials, team information, and general findings. The website is intended to be a resource for the general public and intended users and other researchers seeking basic information on the project. The Collaboration Lead and Assistant also developed an E-Newsletter to communicate preliminary findings, opportunities for future engagement, and basic information about the project.

The project team also developed and presented a poster on the BWM project at the first Cape Coastal Conference organized by the Reserve CTP in partnership with several state, regional and local organizations. The theme of the conference was State of the Cape: Changing Waters and Shorelines and the primary coastal issues addressed included eutrophication, wastewater management, coastal hazards and climate change. The one and half day conferenceattracted over 200 coastal decision-makers, non-governmental organizations, and interested stakeholders. In addition to the BWM poster presentation, Jim Rassman (WBNERR) presented on ongoing research at WBNERR, including the BWM project. The presentation was intended to draw additional

attention to the science, tools, approaches, and research assistance available at WBNERR, including the BWM project.

Additionally, several science team members shared their research with other scientists. Serena Moseman-Valtierra (URI) presented on the team's blue carbon research at the Picarro headquarters in Silicon Valley, which resulted in being featured as one of the "Coolest scientists on earth" (see middle of the following webpage: http://www.picarro.com/). Serena noted that the President of Picarro had not heard of blue carbon before and was impressed with the team's ongoing research. In August 2013, MBL science team intern, Veronica Alston, analyzed plant biomass data and presented at the Woods Hole Partnership Education Program symposium, and in spring 2013, Kate Morkeski (MBL) spoke with eighth graders at the public junior high school in Falmouth about her work.

Intended Users Engagement Objectives for the Next Six Months

- RAE and Steve Crooks anticipate presenting on Coastal Blue Carbon and the methodology at the NERRS Annual meeting in November 2013.
- RAE and Steve Crooks will also be working with the South Slough Reserve to implement a Blue Carbon Demonstration and Dialogue, modeled on the event held at WBNERR in March 2013.
- The project team will plan engagement on the economic component of the BWM project (as discussed on page 19).
- The project team will plan engagement on the model component of the BWM project (as discussed on page 20).
- The project team will kick-off a series of "road show" presentations to intended users, such as town boards and/or state agencies, to share information about the BWM project and to solicit input on how the model and policy analyses could be developed to meet users' needs. This effort will be coordinated by the Collaboration Lead and Assistant.
- The project team will complete a public display board that communicates information about the BWM project, key science concepts, and potential applications. This display board will be available for display in the WBNERR Visitor Center, "road show" presentations and conferences. A vendor has been selected and will begin work once final paperwork is completed by the MA Department of Conservation and Recreation.
- The project team will organize and offer a state of the science "Wetlands, Nitrogen and Wastewater" symposium for state and local decision-makers interested in learning more about how nitrogen pollution affects wetland function as well as the potential implications using wetlands as sites for mitigating nitrogen pollution from wastewater sources. There is great demand among the decision-maker community for information on these topics. Research findings from the BWM will be featured and discussed along with other relevant research being conducted in the state.The project team will plan engagement activities with state and local end users on the GHG methodology and guidance documents and discuss ways to link this layer of engagement with that being led by RAE at the national level.

C. PROGRESS ON PROJECT OBJECTIVES FOR THIS REPORTING PERIOD

GREENHOUSE GAS METHODOLOGY
Lead: Steve Emmett-Mattox (RAE)

RAE is developing a GHG offset methodology for tidal wetlands restoration in the U.S. Over this reporting period RAE made substantial progress toward completion of the draft tidal wetlands greenhouse gas offsets methodology, and expects to submit a draft to the Verified Carbon Standard (VCS) in October 2013. The methodology team met in April-May to work through a number of significant issues and is now drafting the final sections. Primary issues discussed were soil depletion time and peat depletion time, allochthonous/autochthonous carbon, requirements for establishing the baseline scenario, procedures for planning for sea level rise, and procedures for ecological leakage. A fuller description of the Verified Carbon Standard's requirements related to these issues, and others which the methodology must address, are available in the VCS Standard. The project plan also calls for RAE to develop a guidance document for the methodology during year two of the project. This activity has been postponed until the draft methodology has been submitted. RAE has been in conversation with Dr. Igino Emmer, Silvestrum; Dr. Steve Crooks; and Dr. Brian Needelman, University of Maryland, to develop contracts for developing the guidance document.

There have been many challenges which have resulted in a longer time line for developing the methodology. Coordinating a geographically disparate team has been difficult, and the most progress has been made when we convene in person. Some aspects of the methodology have required developing new scientific approaches. One example is how to account for allochthonous sediment carbon, derived from outside of the aquatic system such as plant and soil materials, and autochthonous carbon, derived from the aquatic system such as algae and microbes. The methodology team members reviewed scientific literature and engaged in discussions with colleagues to arrive at rigorous approaches for addressing these questions.

Methodology Objectives for the Next Six Months

- RAE expects a final push to complete the draft methodology and submit to the VCS in October. At that point, RAE will engage the first of two independent consultants to validate the methodology, per VCS requirements. The first round of validation is expected to take six months.
- Once the draft methodology is submitted, RAE will begin work on the guidance document, which should also be complete within six months.
- The project team's advances in how to bring wetlands carbon to market, which are incorporated into the draft methodology, will be shared more widely once the draft has been submitted to the VCS later this fall. Some of this sharing will likely occur in fall 2013 (e.g. at the NERRS annual meeting), but most will likely occur once the methodology has been verified in winter 2014.

WBNERR FIELD AND TECHNICAL SUPPORT
Leads: Jordan Mora, Jim Rassman, , Chris Weidman (WBNERR)

WBNERR continued to play an integral role in providing site infrastructure and *in situ* data collection support to field investigators.

Summer Interns
In March and April, three summer interns were interviewed and hired to participate on the Science Collaborative project. Supervision and instruction was mainly provided by Jordan Mora (WBNERR), with help from Serena Moseman-Valtierra (URI) and Kate Morkeski (MBL) during vertical flux measurements. In addition to the vertical greenhouse gas, plant count, and soil property measurements, the interns also assisted in elevation surveys and belowground and aboveground biomass sampling and processing.

Infrastructural support
In March, sections of the Sage Lot boardwalk were repaired which had been damaged due to frost-heaving effects over the winter months. In early late May/early June, new sections of the Sage Lot boardwalk were constructed: 1) an extension was added at the upland border, and 2) a new platform was added in the high marsh for vertical flux measurements. Additional planks (six-foot, 2 x 10") were built and supplied to access the remote platform in the high marsh. Planks were delivered to the nitrogen gradient sites in March. They have been stored on-site throughout the summer.

Automatic Data Loggers
Onset temperature probes and water level recorders were ordered, deployed, and maintained since the last reporting period. Three temperature probes are currently deployed at each of the four sites measuring soil temperature at depths of 30cm and 15cm and at the soil surface. A fourth temperature probe is deployed 1m above the soil surface measuring air temperature at each site. The probes record average temperature on five minute intervals. Lastly, four water level recorders (pressure gauges) were purchased from Onset and deployed at each of the four sites. They are deployed in 50cm wells and measure water pressure every 10 minutes.

The meteorological station at Sage Lot continues to be monitored and maintained. The station measures photosynthetically active radiation, solar radiation, wind (and gust) speed and direction, and rainfall. Average data is recorded every 10 minutes. The weathervane measuring wind direction had to be tightened twice in late spring and the batteries were replaced in July.
All of the data from the data loggers are downloaded monthly and managed in several large datasets. Some of this data is available on Basecamp, but additional data can be made available by request.

Above- and belowground biomass measurements
In late May, the field science team convened to discuss salt marsh coring strategies to obtain belowground biomass samples. Following this meeting, a Russian peat corer was purchased to extract 50cm cores with 5cm diameter. In June, the first set of aboveground and belowground biomass samples were collected. The June set included aboveground plant clippings for all the collars (four nitrogen gradient sites and both zones at Sage Lot; total = 32 collars), and two

belowground cores were extracted for every low marsh collar (all nitrogen gradient sites; total = 23 collars). We were not able to take high marsh cores due to unforeseen difficulty with the Russian peat corer method. Within a month, all of these samples were processed. In July, the second set of aboveground samples were collected. The July set included aboveground clippings for all the collars (total = 32 collars). These samples were processed within a week. Additionally, in July a subset of collars were sampled for belowground biomass; cores were taken in the low marsh using two different techniques (PVC corer vs. Russian peat corer). These cores were processed within the following week, and the results showed drastic compaction effects associated with the PVC method. In August, a complete set of aboveground and belowground biomass samples were collected all of the collars. These samples are still being processed.

GIS & Elevation Support
Jordan Mora (WBNERR) supplied geographic coordinates for the Science Collaborative team following the March Annual Meeting. The Excel spreadsheet is available on Basecamp. Additionally, new maps of the nitrogen gradient sites and Sage Lot site were uploaded to Basecamp. The team has made progress regarding the habitat map since the last reporting period. The team has been working with the NOAA Coastal Services Center to develop habitat delineations using automatic segmentation software.

Elevation surveys were conducted at all four sites. Vertical flux collar and lateral flux data logger elevations were started last fall (2012) at Sage Lot Pond, but the new collars in the high marsh were surveyed in July. Additionally, with the help of Barry Irwin, USGS, the team was able to acquire corrected North American Vertical Datum (1988) benchmarks at Hamblin, Eel, and Great Pond. Once these benchmarks were established, the WBNERR team collected relative elevations of the vertical flux collars and lateral flux data loggers using a Leica digital level.

Landowner Communication
Landowners were contacted in June through a letter with updates about the project. The WBNERR team has not received any complaints from any of the three sites. Several of the neighbors and landowners make regular visits to see how the study is progressing and chat about findings.

Summary of Data Collected
- Salt marsh soil temperature: soil surface, 15cm depth, and 30cm depth
- Air temperature: (one meter above salt marsh surface)
- Groundwater level**:** 50cm well depth, water pressure (corrected with barometric pressure post-hoc)
- Meteorological station**:** photosynthetically active radiation, solar radiation, wind (and gust) speed and direction, and rainfall
- Aboveground biomass**:** stem count by species within 25cm x 25cm quadrat (placed <1m to collar), canopy height of *Spartina alterniflora* and *Juncus geradii* (10 randomly selected stems within quadrat), dry weight of clipped stems by species, leaf width to biomass ratio.
- Belowground biomass: rhizome dry weight for 10 cm section of 50cm core (core volume = 491 cm^3, section volume = 98 cm^3), root dry weight for 10 cm section of 50cm core (core volume = 491 cm^3, section volume = 98 cm^3), bulk density (core volume = 491 cm^3, section

volume = 98 cm^3). Roots, rhizomes, and sediments were archived for possible future analyses.

The WBNERR team has tried to address unanticipated challenges in belowground coring by combining multiple extraction methods. The team has learned that the high marsh soils are not conducive to coring using the Russian peat corer. Instead, the team had to combine methods to collect samples from all the collars. So far, the team has not had much success in comparing these methods due to compaction effects in the PVC method. However, the team is still working with the data to address the issue and make the data comparable between zones.

WBNERR Field and Technical Support Objectives for the Next Six Months

- WBNERR will focus primarily on habitat map development.
- WBNERR will continue to maintain the automatic data loggers and provide support for vertical flux measurements in the field.

SCIENCE INVESTIGATION AND FIELD RESEARCH
Leads: Kevin Kroeger (USGS), Serena Moseman-Valtierra (URI), Jim Tang, (MBL)

Lateral Flux Measurements
Full seasonal and annual budgets of tidal material exchange at four salt marshes requires a large effort, and the expanded team that has been working on the effort continued to collaborate during this reporting period (Table 1).

Table 1. Direct participants in lateral fluxes effort

Name	Role	Institution
Kevin Kroeger	Principle Investigator	USGS Woods Hole
Neil Ganju	Co-Principle Investigator	USGS Woods Hole
John Pohlman	Co-Principle Investigator	USGS Woods Hole
Adrian Green	Research Technician	USGS Woods Hole
Sandra Baldwin	Research Technician	USGS Woods Hole
Wally Brooks	Research Technician	USGS Woods Hole
Michael Casso	Research Technician	USGS Woods Hole
Charles Worley	Research Technician	USGS Woods Hole
Aleck Wang	Collaborator—inorganic carbon system analyst	Woods Hole Oceanographic Institution
Amanda Spivak	Collaborator—organic carbon system analyst	Woods Hole Oceanographic Institution
Julia Signell	Summer intern; pCO_2 and pH sensor calibrations	Smith College
Alterra Sanchez	Summer intern; pCO_2 and pH sensor calibrations	San Diego State University
Melisa Diaz	Lipid analyses as tracer of organic carbon source	University of Rochester

The major portion of the team's effort this reporting period involved full sensor deployments at Great Pond and Hamblin Pond, discrete sample collections and flux measurements across full tidal cycles, and deployments and testing of a submersible carbon dioxide sensor. The team has now deployed sensors required for continuous measurements of exchange at three study sites: 2 YSI EXO2 multiport optical sondes, a Wetlabs Triplet optical sensor coupled with a YSI sonde measuring non-optical parameters, 3 Sontek IQ ADCPs for measurements of water flow.

With regard to lateral flux measurements, at the Sage Lot Pond site the team now has near continuous data on several chemical parameters beginning in April 2012 until present, and near continuous water fluxes beginning in July 2012 until present. In addition, at Hamblin and Great Ponds the team now has nearly continuous sensor deployments beginning May and June 2013. To calibrate sensors and to calculate net exchanges of carbon and GHG between marsh and estuary, the team conducted comprehensive sample collections during 14 hour full tidal cycle deployments at Sage Lot Pond in April, July and November 2012, and once per month June to August 2013 at Sage Lot Pond, Hamblin Pond, and Great Pond.

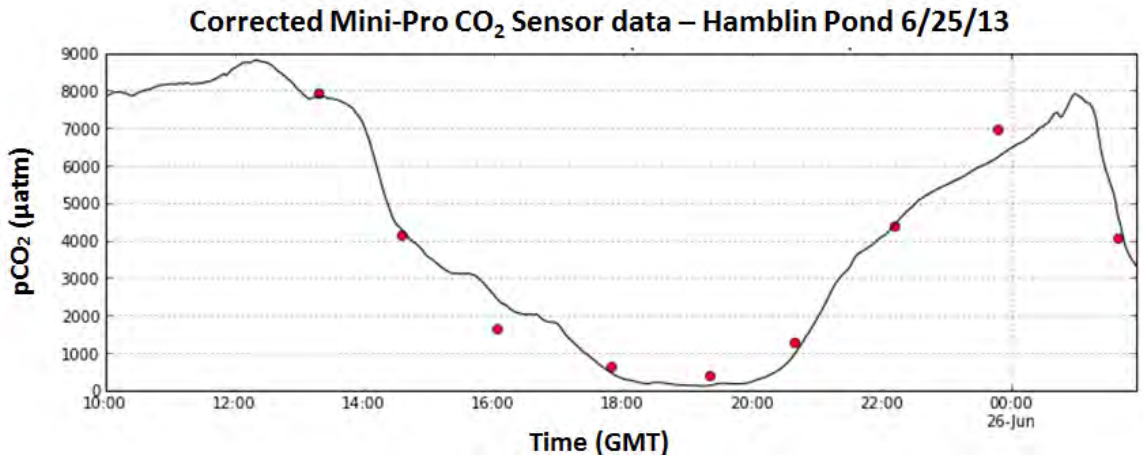
For lateral flux measurements the team is now maintaining sensors at three of the four study sites comprising the nitrogen loading gradient to collect the data that will be the backbone of budget calculations. The sensors (Table 2) will cover several of the needed parameters. However, there are some critical parameters, particularly nitrous oxide and methane, that cannot be readily measured continuously using sensors. Thus, the sensor data is being supplemented with a schedule of 1) full tidal cycle (14 hour) measurements of all chemical parameters including measurements of dissolved GHG using the Picarro gas analyzers (approximately 4 per year per site), and 2) periodic sample collections of ~3 to 4 hours each at particular portions of the tidal cycle

Table 2. Parameters to be measured continuously at each site using sensor deployments

Parameter	Proxy for:	Manufacturer
Integrated water velocity	Water flux	Sontek
CDOM	Dissolved organic carbon	YSI or WetLabs
Suspended particles	Particulate organic carbon; sediment	YSI or WetLabs
pH	Carbon dioxide (under investigation)	YSI
Chlorophyll a	Phytoplankton biomass	YSI or WetLabs
Dissolved oxygen		YSI
Salinity		YSI
Temperature		YSI
Oxidation/reduction potential		YSI
Pressure	Water depth	YSI
pCO_2	Respiratory carbon dioxide; possibly DIC proxy with pH	Pro Oceanus

The team is presently investigating dissolved carbon dioxide sensors to allow continuous measurement of that key GHG and an additional component of the DIC system. During summer 2013, two interns, Julia Signell and Alterra Sanchez, participated in field research and focused their efforts on deploying a ProOceanus CO_2 sensor, and testing sensor performance based on laboratory analysis of CO_2 concentrations (in collaboration with Aleck Wang of Woods Hole Oceanographic Institution. Corrected sensor CO_2 data (Fig 1) reasonably approximated laboratory measured CO_2, though with significant error. The team is currently conducting tests of the sensor under controlled laboratory conditions.

Figure 1:



Vertical Flux Measurements

In tandem with lateral gas flux measurements, vertical GHG fluxes were measured from 4 marsh zones in Sage Lot between June and August of 2013: ponds, low marsh, high marsh, *Phragmites*. The team's focus during this reporting period was on preparing for field data collection during the growing season and collecting field data. Through meetings and discussions with BWM project team members, the team added some parameters to data collection and developed and finalized protocols for others. The team also made progress on improving methods for calculating gas flux from raw gas concentration data and shared these improvements with Serena Moseman's team. During this period the team trained and included four college interns and one high school student in the field and lab team (Table 3).

Table 3. Direct participants in vertical fluxes effort

Name	Role	Institution
Kate Morkeski	Research Assistant	MBL
Jessie Gunnard	Research Assistant	MBL
Lauren Krohmer	Intern	MBL/Northeastern University
Karissa Parker	Intern	MBL/ Boston University
Michael Callahan	Intern	MBL/ University of Massachusetts – Dartmouth

Veronica Alston	Intern	MBL/ Tuskegee University
Jacob Nelson	Intern	MBL/ Sturgis Public Charter School
Matthew Manning	Intern	USGS
Rose Martin	Graduate Student	URI

During the reporting period, the team continued to measure GHG (CO_2, CH_4, and N_2O) flux along with air temperature and associated soil properties and plant biomass at 20 plots distributed among four salt marsh sites receiving different amounts of nitrogen. Soil properties included temperature, pH, salinity, moisture (added in May), and porewater collection for nutrient analysis. The team continued to use the large, novel chamber system (60 cm per side, 0.180 m^3) to measure vertical gas flux. This chamber was connected to the state-of-the-art gas analytical systems for in-situ measurement of N_2O (Los Gatos Research) and CO_2 and CH_4 fluxes (Picarro, Inc.). Air inside the chamber was circulated, and concentration was measured in real time and recorded electronically. The team then calculated gas fluxes based on the rate of concentration change. In April, the team added photosynthetically active radiation (PAR) to the suite of measurements. In March and April, the team collected gas and soil properties data at the four sites comprising the N gradient once each month. During the growing season, i.e. beginning in May, the team made these measurements twice a month. Also in May, the team measured net photosynthesis (i.e. net CO_2 uptake) at the sites for the first time in 2013 and thus began night measurements for the current growing season. With each round of daytime measurements, a subset of plots at the reference site and all plots at one site with elevated N were measured after sunset in order to quantify ecosystem respiration. Night measurements were rotated among the three elevated-N sites so that respiration was measured on all three.

In addition to GHG fluxes, soil properties (salinity, pH, oxidation-reduction potential) were sampled in marsh plots where GHG fluxes were measured. Porewater was collected for nutrient and sulfide analysis between June and Aug. 2013. Temperatures inside of chambers were also recorded.

Plant biomass was measured via two complementary methods: destructive and non-destructive. In the destructive harvests, which occurred three times between June and August, a 25 cm by 25 cm quadrat was placed on the marsh surface approximately a meter away from each gas measurement plot. The height of ten randomly chosen *Spartina alterniflora* stems was measured. (*S. alterniflora* is the dominant species at all low marsh sites). Then all stems within the quadrat were counted, clipped at the sediment surface, and returned to the lab where they were sorted by species, dried, and weighed along with all detritus within the quadrat. Belowground biomass was measured in each clipped plot via the collection of two cores and the subsequent separation of roots, rhizomes, and sediment, and the drying and weighing of the plant tissue. The non-destructive method measured aboveground biomass only. It consisted of counting all stems within a 25 cm by 25 cm quadrat placed *within* each gas sampling method and measuring the height of ten randomly chosen *S. alterniflora* stems. None were clipped. The relationship between stem density, height, and, biomass will be calculated from the clipped samples and applied to calculate biomass from stem density and height in the non-destructively sampled quadrats. Using these two methods, the seasonal development of biomass and annual production were accurately measured via harvests, and the biomass within in the plots where gases were directly measured was quantified as well without damage.

In June and July the team analyzed ammonium in all of the porewater samples collected to date.

The team's progress in this period has brought about several changes to its methods. They include:

- Adapting and implementing a previously published Matlab script for calculating gas flux from raw concentration data as well as mean air and sediment temperature from raw temperature data.
- Shortening the gas data collection duration (i.e. chamber deployment time) when appropriate. Processing flux data showed us that a long time interval (>5 min) is not always necessary and can slow down data processing. When the slope of concentration change is steep, a duration <5 min is preferable to minimize chamber effects and make field data collection as well as later data processing more efficient.
- Adding PAR to the parameters measured.
- Adding soil moisture to the parameters measured.
- Adding non-destructive aboveground plant biomass to the parameters measured.
- Specifying the methods for belowground biomass measurement.

An unanticipated challenge occurred in July, when both of the team's gas analyzers had technical malfunctions that prevented the team from using them for the early July sampling date. Serena Moseman provided a Picarro analyzer from another project for use at Sage Lot Pond for that date. With support from the manufacturers and computer expertise at MBL, the team was able to fix both analyzers in time for the late July sampling. An unexpected opportunity was the chance to demonstrate the analyzers to the general public at MBL's Discovery Day on July 17 (Fig. 2).

Figure 2. Demonstrating the gas analyzers and their real-time displays to the general public at the Marine Biological Laboratory's Discovery Day, 17 July 2013. (Photo: Melissa Campbell)

Additionally, data analysis has been slower than expected and almost impossible with a heavy field schedule. The team is learning to use Matlab and hopes to become more proficient at this during the next few months.

Preliminary Findings

1) The data have not yet been analyzed but from examining the patterns in the field, there seems to be larger uptake of CO_2 in the low than the high marsh. CH_4 emissions are generally small but have been observed on occasion to be as high from ponds as they are from marshes. *Phragmites* zones may have larger CO_2 consumption and CH_4 emission than native marsh zones.

2) Porewater ammonium concentration is consistently higher at the high-N sites (Eel Pond and Great Pond) than at the moderate-N (Hamblin Pond) and reference (Sage Lot Pond) sites (Fig. 3).

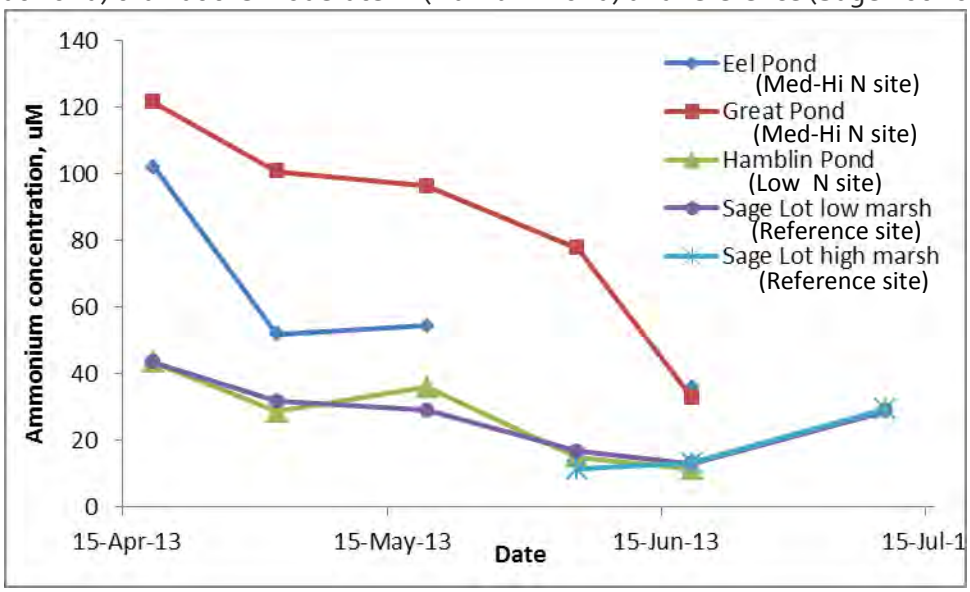


Figure 3. Mean porewater ammonium concentration (µM) at the four low marsh sites and the high marsh site. Each data point represents the average of all plots at that site on that date.

Aboveground plant biomass at the low marsh sites was overwhelmingly dominated by *S. alterniflora* (Fig. 4). *S. alterniflora* biomass ranged from 276 g/m^2 at Sage Lot Pond in June 2013 to 745 g/m^2 at Eel Pond in August 2012 (Fig. 5). June and July data suggest that higher N status may be associated with earlier peak in aboveground biomass. Forthcoming August 2013 data may support this pattern. Standing crop of dead biomass (Fig. 5) is markedly lower at Eel Pond and Great Pond than at Hamblin Pond and Sage Lot Pond, despite similar live biomass among all sites in August 2012 (Fig. 5). These results suggest that detrital processing is accelerated at the high-N sites relative to the moderate-N and reference sites.

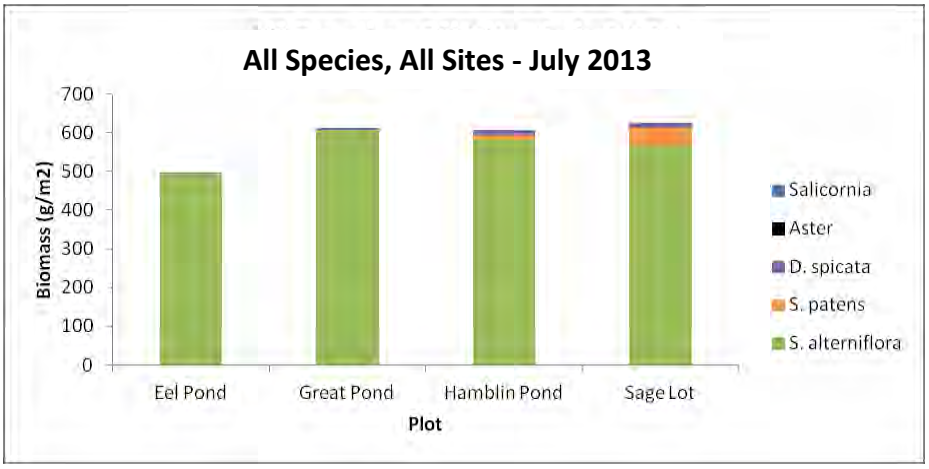


Figure 4. Mean biomass of plant species collected from the low marsh sites in July 2013.

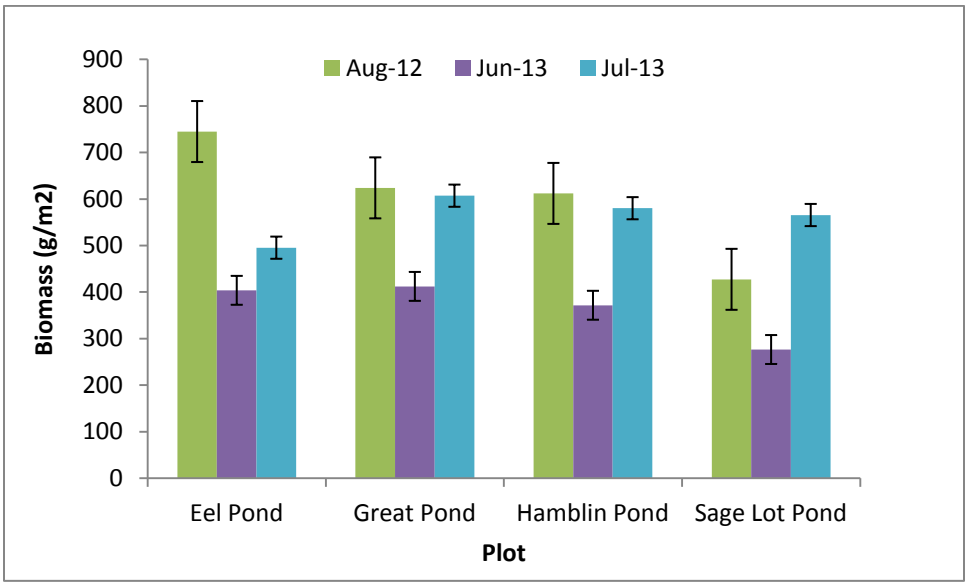


Figure 5. Mean biomass of *Spartina alterniflora* at the four low marsh sites in August 2012 and June and July 2013. Error bars are one standard deviation.

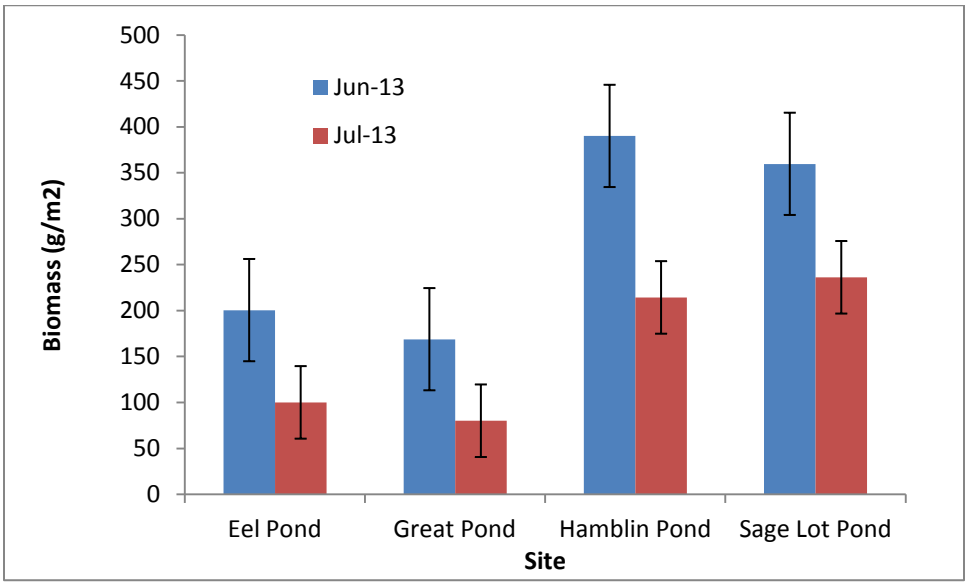


Figure 6. Mean detritral biomass at the four low marsh sites in June and July 2013. Error bars are one standard deviation.

3) The team's calculations of gas flux to date are limited and so far indicate a large amount of variability among sites and dates (Figs 7-9). The team will finish calculations of all 2012 data and share with the modeling team by 30 Aug 2013. The team plans to focus on calculations and analyses of the 2013 data in the next reporting period.

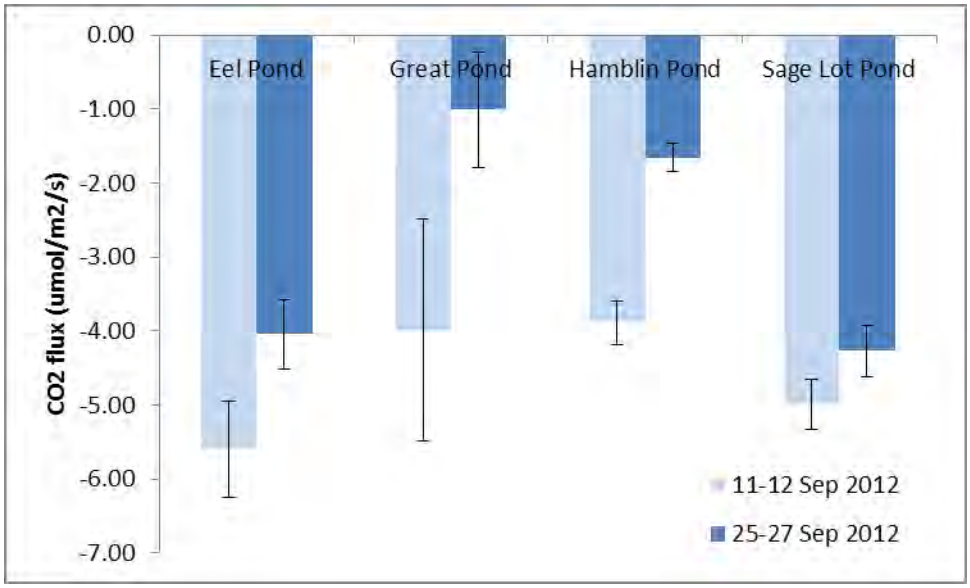


Figure 7. Mean daytime carbon dioxide flux at the four low marsh sites on the two sampling occasions in September 2012. Error bars are one standard error.

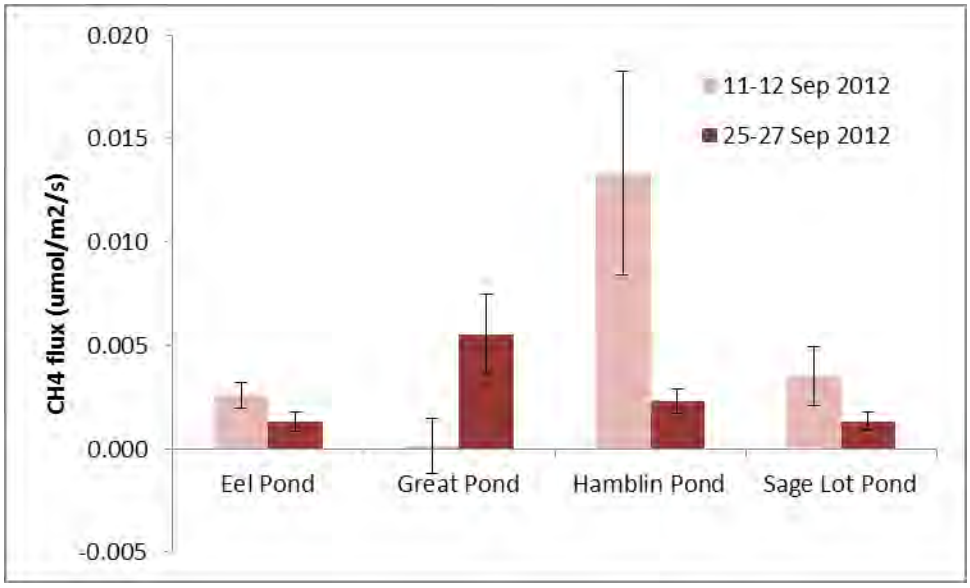


Figure 8. Mean daytime methane flux at the four low marsh sites on the two sampling occasions in September 2012. Error bars are one standard error.

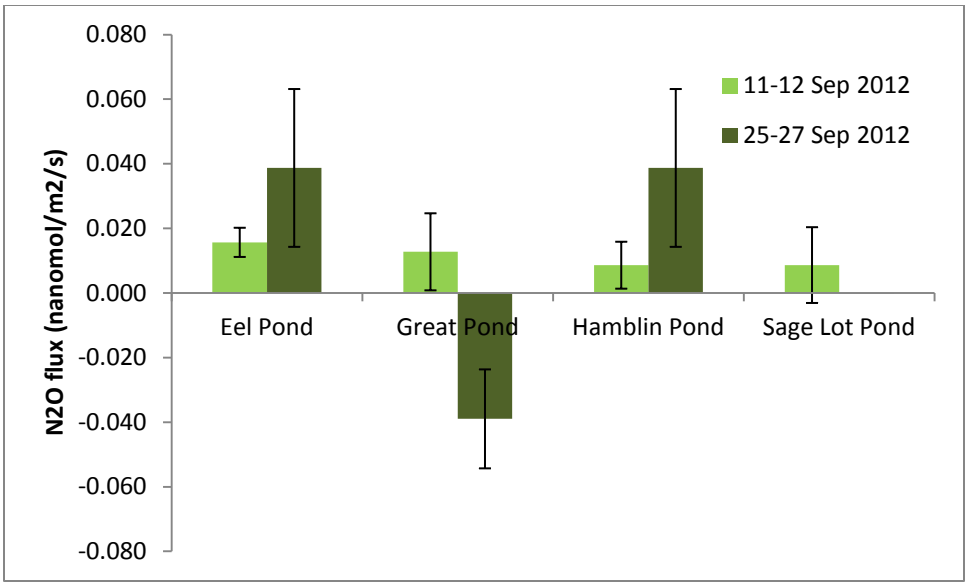


Figure 9. Mean daytime nitrous oxide flux at the four low marsh sites on the two sampling occasions in September 2012. Error bars are one standard error.

Science Investigation and Field Research Objectives for the Next Six Months

- The team will continue to analyze environmental field data from the first field season and by 30 Aug 2013, will share with modeling team all 2012 data and by December 2013, will calculate all gas fluxes from data collected through August 2013.
- The lateral flux team expects to maintain the current sensor deployments and discrete sample collections schedule described here, to complete a full year of flux data in tandem with vertical flux measurements.
- The lateral flux team will also continue investigation of CO_2 sensor performance, and intends to acquire one or two more sensors.
- The vertical flux team will complete analysis for all porewater samples for ammonium and nitrate.
- The vertical flux team will adapt Matlab script used for temperature calculations to also handle PAR data.
- The vertical flux team will continue monthly sampling of gas flux and soil properties at the four sites through December 2013.
- The emphasis will be on data analysis and presentation of results at UMass Amherst (where Moseman-Valtierra was invited for a seminar in September), at the national conference of the Coastal and Estuarine Research Federation in November, and at other meetings with intended users (as appropriate and relevant).
- Science team member Serena Moseman-Valtierra is also expecting a baby at the end of December.

BIOGEOCHEMICAL MODEL
Lead: Omar Abdul-Aziz (FIU)

The conceptual framework of the proposed user-friendly GHG emissions and C-sequestration model was tested in the last six months by using large scale GHG flux data, gathered from the Ameriflux network. The team gathered 30 minute interval data of 2006-11 for 11 climate/environmental variables and two types of forest canopy-scale GHG variables: (i) vertical CO_2 fluxes for eight deciduous forest sites of northeastern USA, and (ii) net ecosystem exchanges (NEE) for six different vegetation types of eastern USA. The data sets were rigorously analyzed by employing advanced data mining and pattern recognition techniques (e.g., Principle Component Analysis, Factor Analysis) and much insight was obtained into the relevant biogeochemical processes.

The results showed the relative influences and linkages of contrasting climate and environmental drivers on the GHG fluxes. The findings were leveraged to develop multiple regression-based empirical models to predict GHG fluxes using data of dominant climate and environmental variables. Impressive modeling performance (e.g., accuracy and fitting efficiency) for different sites indicated that data-driven, empirical models can be useful and very user-friendly tools, compared to their more complex process-based counterparts, for predicting ecosystem GHG fluxes under changing environmental conditions.

Much data from WBNERR sites were collected by the field science team in 2012 and are currently being revised to final formats. The team had previously analyzed the preliminary datasets prepared by the field team and provided important feedback on trends and correlations of GHG fluxes with environmental variables. Insights obtained from the preliminary analysis were shared with the team members to augment the future field campaigns by collecting data on new variables such as soil porosity, light, soil temperature which will support the work of the modeling team and intended users.

Biogeochemical Model Objectives for the Next Six Months

- The team is currently preparing two manuscripts to submit for peer-reviewed journal publications in the next couple of months.
- The model team will work with the field scientists to obtain the final data sets of the field sites from 2012.
- Using the data, the team expects to develop a beta-version of the wetland GHG model for use by coastal decision-makers;
- The project team will begin initial planning for intended user participation in testing and refining the beta version of the model.

ECONOMIC AND POLICY ANALYSES
Lead: Tom Walker (Manomet)

During the reporting period, work began on detailing the scope of work for the economic and policy analyses. Tom Walker developed a more detailed economic analysis options for the consideration of the BWM team. He scoped several options based on discussion at the BWM project team meeting (March 2013) and on input gathered from intended users at the Working Together To Get Things Done Workshop (April 2012). The options were presented to the team for comment and further refined by Tom Walker based on available data and team objectives and comments.

Tom Walker also researched data availability to support the economic analysis, including restoration project data and modeling from MA Division of Environmental Restoration (MA DER). Tom Walker and Steve Emmett-Mattox spoke with Jeremy Bell, Restoration Specialist, MA DER (and potential intended user) about data availability to support economic analysis, including: 1) the list of tidal flow projects that have been completed by DER or identified for future implementation on the Cape and more broadly in Massachusetts; 2) any available data about the area affected by restoration and the costs of the projects; 3) any past data on changes to the ecosystems that resulted from previously implemented projects; 4) data or modeling results on changes in salinity that would allow us to project impacts for projects not yet completed.

Preliminary review of the information Jeremy Bell provided suggests that there is information available for a limited number of restored sites that could be used to estimate carbon impacts for future salt marsh restoration projects on the Cape. This could probably be used to come up with screening level estimates of restored area per dollar expended on removal of tidal restrictions. Combined with the information on the areal extent of projects not yet implemented, this could then form the basis for estimating net carbon flux associated with restoration projects of different scales.

Economic and Policy Analyses Objectives for the Next Six Months:

- Develop final recommendation on a proposed economic analyses.
- In coordination with WBNERR, conduct outreach to intended-users to gather feedback on the proposed scope of analyses.
- Begin economic analyses based on team and intended-user feedback.

Team Coordination

The team held a face-to-face BWM team meeting in March 2013 to discuss workplans, data needs, and project logistics. As a result of the face-to-face meeting, several changes to the data collection methodology and parameters were made. Additionally, the meeting resulted in a more refined vision for the economic and policy analysis.

The project team continued to use Basecamp as a communication and project management tool.

Throughout the reporting period, the team held monthly conference calls facilitated by the Collaboration Lead to share project updates, discuss intended user feedback, and provide input on

project tools and resources (e.g. website, multimedia communication and science translation products).

D. BENEFIT TO NERRS AND NOAA

During this reporting period, WBNERR completed work on one transfer- ideas-to-other-NERRS projects: 1) Blue Carbon Demonstration and Dialogue and continued work on another 2) BWM module development for Teachers on the Estuary Program. The goal of these projects is to transfer lessons and ideas from the BWM project to other NERRS.

Blue Carbon Dialogue and Demonstration Project: The Science Collaborative-funded a transfer project on the applications of blue carbon at the NERRS. The dialogue took place at WBNERR in March 2013. See page 4 for additional information.

BWM Teachers on the Estuary Module Development - With support from a NERRS Science Collaborative Transfer Grant, Joan Muller, Education Coordinator at WBNERR and Tom Gaskill, Education Coordinator at the South Slough NERR in Oregon, developed an education unit for middle and high school teachers and students about the BWM project. A draft of the learning module was completed this spring and input was gathered from the Waquoit Bay Reserve K-12 Teacher Advisory Committee, WBNERR staff members working on the BWTM project, and several other members of the BWTM team (thanks to Jim Tang and Tom Walker for their written comments, Serena for contributing amazing images of salt marsh corings, and Steve Crooks for participating in a telephone focus group to gather input). Some of the activities were tried out with a small group of high school students in the Reserve's TIDAL Quest program. TOTE (Teachers on the Estuary) workshops were quickly filled to capacity on both Cape Cod and at the South Slough Reserve in Oregon.

The east coast TOTE was held in Waquoit August 12-15, with 13 middle and high school science, math, and technology/engineering middle and high school teachers from around Massachusetts plus a Mass Audubon educator who will be educating about these topics to other educators. The teachers enjoyed the trying out the activities and visiting the study site (thanks to Serena Moseman-Valtierra, Kate Morkeski, Jessie Gunnard, and James Rassman for demonstrating and talking to the teachers at the site) and gave great feedback and suggestions. The following week 15 teachers attended the TOTE program in Oregon. The teachers are looking forward to piloting the activities and coming back in November to contribute more feedback based on their experiences with their students so the curriculum can be finalized in December. The team's contractor, Pat Harcourt developed an excellent wiki which contains the draft curriculum (comments and suggestions welcome at any time as well as many other supporting documents and resources which can be visited at http://bluecarbon.wikispaces.com/

Economic Valuation Working Group – inspired by the Salt Marsh Symposium held in January at WBNERR, Jacques Cousteau Reserve Manager Mike Deluca has started a System-wide conversation/workgroup on the valuation of ecosystem services (by any method). The assessment team includes staff from the Science Collaborative and others. The group is currently discussing the best approach to bring this topic the NERRS annual meeting in November.

E. Describe any activities, products, accomplishments, or obstacles not addressed in other sections of this report that you feel are important for the Science Collaborative to know.

This project has contributed to a number of other follow-on proposals involving members of the Team. These include:

- Awarding of National Science Foundation award to Omar Abdul-Aziz to further develop the biogeochemical model through "a Wetland Similitude & Scaling project"
- Awarding by the NERRS Science Collaboration of a transfer grant to the South Slough NERR and Steve Emmett-Mattox (RAE) to build on the Blue Carbon Demonstration piloted at WBNERR in March 2013.